Current Research in Internet of Things

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Abstract

The aim of this study was to review the studies on the Internet of Things. Various databases were searched for keywords like ‘Internet of Things’, and ‘Internet of Things & Smart Cities’ etc. The results were shortlisted as per the year of publication and a few of the studies were selected for a review. The review found that Internet has become ubiquitous and that in the future, the Internet of Things will be the predominant trend. There have been studies which have been carried out on the efficacy of the Internet of Things and its application is various fields such as healthcare. The Internet of Things has also been used in concepts such as smart homes and smart cities.

Keywords: Internet of Things (IoT), Review, Trends, Current Research

Introduction

The Internet is everywhere today. According to Sethi & Sarangi (2017), today the Internet has become omnipresent – “it has touched almost every corner of the globe, and is affecting human life in unimaginable ways. We are now entering an era of even more pervasive connectivity where a very wide variety of appliances will be connected to the web. We are entering an era of the “Internet of Things””. The future will be driven by the Internet of Things.

The Internet of Things has seen great development in the past few years. According to Madakam, Ramaswamy & Tripathi (2015), the development of the Internet of Things (IoT) has been principally propelled by the requirements of large corporations which will gain advantage from “the foresight and predictability afforded by the ability to follow all objects through the commodity chains in which they are embedded”. The capacity to code and track objects has empowered companies by becoming “more efficient, speed up processes, reduce error, prevent theft, and incorporate complex and flexible organizational systems through IoT” (Madakam, Ramaswamy & Tripathi, 2015).

The development of the Internet of Things has also been the result of technological innovations which have been happening over the past few decades. According to Madakam, Ramaswamy & Tripathi (2015), the IoT is a “technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology. They are going tag the each object for identifying, automating, monitoring and controlling”.

According to Chen, Miao, Hao, & Hwang (2017), IoT has achieved significant improvement in big data processing, heterogeneity, and performance. According to Madakam, Ramaswamy & Tripathi (2015), the future is Internet of Things, which will convert real world objects into intelligent virtual objects. “The IoT’s objective is to unify everything in our world under a common infrastructure, giving us not only control of things around us, but also keeping us informed of the state of the things” (Madakam, Ramaswamy & Tripathi, 2015).

According to Wollschlaeger, Sauter, and Jasperneite (2017), the adoption of IoT technologies and concepts in automation will grow substantially. These technologies need to be evaluated and need to be further tailored to industrial automation needs.

Methodology

In this paper, we will review some of the research studies which have been carried out on the subject of Internet of Things. Towards this end, specific search terms were used in Google Scholar search engine, such as 'Internet of Things', and 'Internet of Things & Smart Cities' etc. The results of these searches were shortlisted as per the year of publication. For the purpose of this study, only studies published after 2010 were used, in order to review the studies on Internet of Things.

Results and Discussion

According to Zachariah, Klugman, Campbell, Adkins, Jackson, & Dutta (2015), "the vision of an Internet of Things (IoT) has captured the imagination of the world and raised billions of dollars, all before we stopped to deeply consider how all these Things should connect to the Internet". A recent McKinsey report estimates the economic impact of the Internet of Things (IoT) to be between USD 3.9 to USD 11 trillion dollars by 2025 (Alur, Berger, Drobnis, et al., 2015). Academia is of the view that IoT has the "potential to have a profound impact on our daily lives, including technologies for the home, for health, for transportation, and for managing our natural resources" (Alur, Berger, Drobnis, et al., 2015).

Previously, the Internet was principally powered by the people, and the ideas and information they generated. As per Alur, Berger, Drobnis et al. (2015), progress in hardware and sensing technology has equipped computers to observe the physical world more easily. This extra available information, along with the developments in machine learning has brought about "dramatic new capabilities including the ability to capture and process tremendous amounts of data; to predict behaviors, activities, and the future in uncanny ways; and to manipulate the physical world in response" (Alur, Berger, Drobnis, et al., 2015). According to the authors, this trend will essentially change how people interact with physical objects and the environment. According to Alur, Berger, Drobnis, et al., (2015), "success in developing value-added capabilities around IoT requires a broad approach that includes expertise in sensing and hardware, machine learning, networked systems, human-computer interaction, security, and privacy". In order to make IoT both practical and to spur its mass adoption, it would need a multifaceted approach that often surpasses technology, such as with concerns over data security, privacy, public policy, and regulatory issues.

IoT System

According to Alur, Berger, Drobnis, et al. (2015), the major components already exist in specific instances and currently companies are competing to become the de facto platform for such devices. The components are:

1. Hardware devices that are able to sense and interface with the physical world
2. Data collected on the behalf of the user by these devices
3. IoT hubs that funnel data from the physical world to the cloud
4. An IoT marketplace with value-added apps that interact with devices and the cloud
5. Services, large and small, that the apps connect to (could be one or more, could be a vertical device-app-service, or could be stratified)
6. Varying sizes of data stores, including federated data stores that normalize data from heterogeneous sources, that the services maintain (collected from the apps and devices)

Recommended Practices

In their study, Alur, Berger, Drobnis, et al. (2015) state that the existing best practices in building robust and secure systems are inadequate for addressing the new challenges that IoT systems will present. Their study provides recommendations regarding investments in research areas that will help address inadequacies in existing systems, practices, tools, and policies.

Smart Homes and Smart Cities

According to Sun & Ansari (2016), today, a large number of smart devices and objects are embedded with sensors, empowering them to sense real-time information from the environment. “This phenomenon has culminated in the intriguing concept of the Internet of Things (IoT) in which all smart things, such as smart cars, wearable devices, laptops, sensors, and industrial and utility components, are connected via a network of networks and empowered with data analytics that are forever changing the way we work, live, and play” (Sun & Ansari, 2016).

According to Alur, Berger, Drobnis, et al. (2015), smart homes have been a dream for decades, but the lack of practical technology, such as low cost, easy-to-deploy, low maintenance, etc., has frequently limited large-scale distribution and mainstream adoption. Another challenge facing smart homes is a matter of retrofitting, as fewer brand new homes are going to be built over the next few decades. Alur, Berger, Drobnis, et al. (2015) say that emerging IoT technologies have the potential to combat this challenge by empowering consumers to instrument their own homes. Such instrumented homes can provide peace of mind for homeowners on both the health and the condition of the home. They can warn of emerging problems before they become too costly. The study by Alur, Berger, Drobnis, et al. (2015) says that homeowners can also use IoT technology to both monitor and manage energy and water usage in their homes. With the utility grids getting “smarter,” the home also needs to get smarter in order to take advantage of energy reduction and conservation strategies. IoT technology for the home, in the future, will be essential for informing “the technologies that eventually get embedded into homes and home appliances” (Alur, Berger, Drobnis, et al., 2015).

According to Sun, Song, Jara, & Bie (2016), “with more than 50 percent of world population living in cities and nearly 70 percent of world population projected to live in cities by 2050, it is expected that cities will face various challenges from sustainability and energy use to safety and effective service delivery”.

According to Alur, Berger, Drobnis, et al. (2015), “smart cities provide a major use case for the Internet of Things”. Quoting a McKinsey report, the authors say that cities are the second or third largest target area for IoT, with “a projected economic impact totaling somewhere between $1 trillion and $1.6 trillion by 2025” (Alur, Berger, Drobnis, et al., 2015). Their study highlights pilot projects for smart cities in India and China, which have nearly 300 smart cities. For example the Barcelona smart city has been around since 2012, and at present, has “83 separate projects that fit into one of twelve target areas: environmental, information and communications technology, mobility, water, energy, matter (waste), nature, built domain, public space, open government, information flows, and services” (Alur, Berger, Drobnis, et al., 2015). Such a smart city has resulted in decreased costs and increased revenues and also contributed nearly 50,000 new jobs. Singapore is also making significant investment toward becoming a "Smart Nation," “providing open access to a vast array of government data from many sources, much of it in real time, in a strategic effort coordinated out of the Prime Minister's Office” (Alur, Berger, Drobnis, et al., 2015). Another benefit cited frequently is the improved quality of life.

According to Alur, Berger, Drobnis, et al. (2015), the benefits provided by the smart city movement are also accompanied by a variety of challenges which need concerted research efforts in systems computing. The authors are of the opinion that many of the benefits of smart cities are due to the new and unique ability “to monitor and track the activities of citizens on a massive scale, in spaces that, while public, have traditionally enjoyed significant anonymity. This pervasive tracking of citizens raises serious issues of privacy and security”. The authors say that there are an extremely large number of systems in a city which could be brought online potentially; hence, standards for communications protocols and data sharing will play an important role. Another challenge would be the sheer quantities of data which could be collected in a medium sized smart city. The authors say that the administration of city resources has involved “managing tradeoffs with the goal of delivering services to citizens at cost-benefit ratios they consider acceptable: the rapid, highly disruptive nature of the transition to smart cities along with a lag in technical expertise among city leaders could lead to lost opportunities and perhaps even degradations in quality of life from the very inventions intended to improve it” (Alur, Berger, Drobnis, et al., 2015). Education and civic participation have important roles to play in this, along with technologies for aiding humans to understand the complex functioning of city systems and the data they generate, and to participate in using this data for decision-making (Alur, Berger, Drobnis, et al., 2015).

Home Network Topology

According to Barcena & Wueest (2015), today’s home networks are characteristically made up of a broadband router which offers internet access to various devices through Wi-Fi and Ethernet connections. Most of the devices that connect to these home networks include laptops, desktop computers, and mobile devices, such as phones and tablets. These devices are all connected in the local network and can communicate freely with one another. Connections to the internet are directed through the central router, which may contain elementary firewall filtering functionality (Barcena & Wueest, 2015).

According to Barcena & Wueest, (2015), as the Internet of Things (IoT) finds its way into most homes today, there are many devices which can connect to the same network. These devices can be classified in two basic categories – the first category includes TV set-top boxes, and uses already-existing networking technologies such as Wi-Fi and Ethernet connections; and the other includes sensors, and may use different wireless technologies that better suit some of the devices’ needs, such as lower energy consumption or ad-hoc network coverage. Barcena & Wueest, (2015), currently, there is no single standard protocol in IoT.

In their study, Barcena & Wueest, (2015) have seen IoT devices that which support some of the following communication methods:

1. Z-Wave
2. Zigbee
3. Powerline
4. Bluetooth 4.0
5. Other radio frequency (RF) protocols

According to Barcena & Wueest, (2015), at present, Z-Wave, Zigbee and Powerline are the most common protocols used by home automation manufacturers. There are some hybrid solutions that use both Powerline and custom RF protocols. Among the smart hub devices that the authors tested in their study, 66 percent offered Z-Wave and 48 percent offered ZigBee connectivity (Barcena & Wueest, 2015).

According to Barcena & Wueest, (2015), devices that use a single wireless connectivity protocol frequently depend on on a central hub device to handle the coordination of the communication. “Due to IoT’s need to use simple integrations and the broad use of the IEEE 802.11 wireless standards, many new devices have switched to regular Wi-Fi for communication where possible. Some classes of devices try to provide every possible option for connection. Out of all of the devices we looked at, 58 percent supported Wi-Fi connectivity” (Barcena & Wueest, 2015).

Narrow Band Internet of Things

According to Chen, Miao, Hao, & Hwang (2017), in recent years, due to the development of IoT, the IoT communication technologies have become developed and extensive. From the perspective of transmission distance, IoT communication technologies can be categorized into short-distance communication technologies and WAN communication technologies. The former is represented by Zigbee, Wi-Fi, Bluetooth, Z-wave and etc. and their typical application is a smart home. WAN communication technologies are visible in low-data-rate services like smart parking mentioned above, which is generally defined by industry as the Low-Power Wide-Area Network (LPWAN) technology Chen, Miao, Hao, & Hwang (2017).

According to Chen, Miao, Hao, & Hwang (2017), the Narrow-Band Internet of Things (NB-IoT) is a massive Low Power Wide Area (LPWA) technology “proposed by 3GPP for data perception and acquisition intended for intelligent low-data-rate applications”. The typical applications are smart metering and intelligent environment monitoring. “The NB-IoT supports massive connections, ultra-low power consumption, wide area coverage and bidirectional triggering between signaling plane and data plane” (Chen, Miao, Hao, & Hwang, 2017). Besides, it is supported by an excellent cellular communication network. Therefore, NB-IoT is a promising technology (Chen, Miao, Hao, & Hwang, 2017).

Energy Management

According to Ejaz, Naeem, Shahid, Anpalagan, & Jo (2017), the radical upsurge in urbanization over the past few years requires “sustainable, efficient, and smart solutions for transportation, governance, environment, quality of life, and so on”. The Internet of Things offers many urbane and omnipresent applications for smart cities. The energy demand of IoT applications is increased, while IoT devices continue to grow in both numbers and requirements. Therefore, smart city solutions must have the ability to efficiently utilize energy and handle the associated challenges (Ejaz, Naeem, Shahid, Anpalagan, & Jo, 2017). Energy management has been classified into two levels: energy-efficient solutions and energy harvesting operations.

According to Ejaz, Naeem, Shahid, Anpalagan, & Jo (2017), energy-efficient solutions for IoT-enabled smart cities include a “wide range of topics such as lightweight protocols, scheduling optimization, predictive models for energy consumption, a cloud-based approach, low-power transceivers, and a cognitive management framework”. According to Ejaz, Naeem, Shahid, Anpalagan, & Jo (2017), energy harvesting allows IoT devices to harvest energy from ambient sources. The aim of energy harvesting is to increase the lifetime of IoT devices. “The research topics included within both types of energy harvesting are energy harvesting receiver design, energy arrival rate, placement of a minimum number of dedicated energy sources, scheduling of dedicated energy sources, and multi-path energy routing" (Ejaz, Naeem, Shahid, Anpalagan, & Jo, 2017).

Healthcare

Alur, Berger, Drobnis, et al. (2015) recommend that an Internet of Healthcare Things (IoHT) can become revolutionary in the field of medicine, healthcare delivery and consumer health. "Smart medical devices, including smartphones, watches, and other bio-based wearables connected in an IoHT, can provide improved, pervasive, cost-effective, and personalized medical care and wellness. An IoHT can also improve hospitals, nursing homes, assisted living, and continuous care retirement communities in many ways" (Alur, Berger, Drobnis, et al., 2015). For example, in hospitals, technologies such as automated hand washing systems, caregiver reminders, locating devices, and automated linking of device-produced medical data with medical records can advance both the operation and safety of hospitals.

Alur, Berger, Drobnis, et al. (2015) recommend that an "IoHT can not only monitor, but also support interventions and assistance. Plug-n-play devices, usable interfaces for not only the healthy, but also for the senior adults and people with disabilities, techniques to handle large volumes of data to avoid overwhelming caregivers, and studies that demonstrate the true medical value of the IoT technology are needed for the large-scale adoption of IoT home-based healthcare. A true global IoT infrastructure has the potential to revolutionize the practice of medicine and transform how people manage their health".

According to Islam, Kwak, Kabir, Hossain, & Kwak (2015), medical care and health care denote one of the most attractive application areas for the IoT. "The IoT has the potential to give rise to many medical applications such as remote health monitoring, fitness programs, chronic diseases, and elderly care. Compliance with treatment and medication at home and by healthcare providers is another important potential application. Therefore, various medical devices, sensors, and diagnostic and imaging devices can be viewed as smart devices or objects constituting a core part of the IoT" (Islam, Kwak, Kabir, Hossain, & Kwak, 2015).

According to Islam, Kwak, Kabir, Hossain, & Kwak (2015), IoT-based healthcare services are expected to decrease costs, improve the quality of life, and augment the user's experience. From the perspective of healthcare providers, the IoT has the potential to lessen device downtime through remote provision. IoT can correctly identify optimum times for replenishing supplies for various devices for their smooth and continuous operation (Islam, Kwak, Kabir, Hossain, & Kwak, 2015). Further, the IoT provides for the efficient scheduling of limited resources by guaranteeing their best use and service of more patients (Islam, Kwak, Kabir, Hossain, & Kwak, 2015).

According to Islam, Kwak, Kabir, Hossain, & Kwak, (2015), IoT is an important trend, mainly due to ease of cost-effective interactions through seamless and secure connectivity across individual patients, clinics, and healthcare organizations. "Up-to-date healthcare networks driven by wireless technologies are expected to support chronic diseases, early diagnosis, real-time monitoring, and medical emergencies" (Islam, Kwak, Kabir, Hossain, & Kwak, 2015). Gateways, medical servers, and health databases play essential roles in creating health records and delivering on-demand health services to relevant stakeholders.

According to Islam, Kwak, Kabir, Hossain, & Kwak, (2015), "the IoT healthcare network or the IoT network for health care is one of the vital elements of the IoT in health care. It supports access to the IoT backbone, facilitates the transmission and reception of medical data, and enables the use of healthcare-tailored communications”.

Conclusion

In this paper, the studies which have taken place on the subject of the Internet of Things, have been reviewed. The Internet of Things has been gaining popularity very quickly and promises to be a trend in the future. It also has potential for application in various aspects of life. Authors have talked about its application in the field of healthcare. Concepts such as smart cities and smart homes have been discussed.

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